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LIFTING SURFACE FOR AIRCRAFT

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16. Abstract

A pre-World War 2 German patent is described for an airplane wing whose profile is automatically changed as a function of the flight parameters (velocity, angle of attack, etc.) in such a manner that the center of pressure always remains approximately at the same place. The patent also includes an automatic steering device for aircraft. Conventional and wing-only aircraft are considered.

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LIFTING SURFACE FOR AIRCRAFT*

Charles Fauvel**, Henri Coltel***

/1**** The invention involves a lifting surface for aircraft, especially airplanes, whose profile is variable by means of moveable flaps or similar items which are mounted on at least one edge of the surface.

The essential feature of the present invention consists in having a variability of the lifting surface profile, as a function of the angle of attack, and automatic steerage in such a manner that the resulting pressure center is always situated at least approximately at the same place.

Actually, lifting surfaces are known for aircraft and similar objects, for which the resulting pressure center remains constant for variable angle of attack by means of a corresponding refinement of the constant lifting surface profile. The known lifting surfaces, however, are frequently unfavorable in their flight properties, and furthermore, strong torsion frequently arises at their fastening point. These disadvantages are avoided, as has been discovered, by

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obtaining a stationary pressure point by means of a variable lifting surface profile as a function of the angle of attack of the lifting surface.

For steering rudders, especially for ship rudders, it is already known how to attach auxiliary surfaces or auxiliary flaps, with whose help the center of pressure remains at a fixed point. Here, however, holding the center of pressure stationary only serves the purpose of holding constant the force which is necessary for moving the rudder, independent of the instantaneous position of the rudder. The special effects which occur when the invention is applied to lifting surfaces of aircraft do not occur for the above rudder surfaces.

According to a further development of the invention, the following fact is also taken into account: changing the velocity of the surface can cause a change in the position of the resulting pressure center. According to this further development of the invention, a control device is provided which responds to the surface velocity, and by means of which the surface profile is automatically variable - even for changing velocity - in such a manner that the pressure center always stays at least approximately at the same place.

The elements which serve automatically to change the surface profile can be coupled to an indicating device for the angle of attack for the lifting force, or they can be coupled to a pendulum, a gyroscope, a velocity or an acceleration indicator, a height measuring device, a statoscope or similar apparatus, to the motor(s) or to a device for automatic airplane steering.

Further characteristics of the invention are seen from the following description of the figures, which represent se- /2

veral examples of application of the invention.

In the drawings we have the following:

Figures 1a, 1b, 1c represent the profile of the lifting surface of an aircraft in three variations, which differ from one another by means of their angle of incidence.

Figures 2a, 2b, 2c also show three different variations of a lifting surface, in cross section, which is composed of several elements in order to vary the profile.

Figure 3 represents a similar lifting surface, which consists of an even larger number of individual pieces in order to change the profile.

Figure 4 represents schematically, in perspective, a wing fitted with flaps.

Figure 5 shows a similar wing with an arrangement of flaps which corresponds to a further development of the invention.

Figure 6 also shows, in cross section, a wing according to a changed form of development for the invention.

Figures 7 and 8 explain certain size ratios, with the help of an airplane lifting surface represented in perspective and developed according to the invention. The lifting surface has constant depth in Figure 7 and variable depth in Figure 8.

Figures 9 and 10 show a side view of two different forms of development of an airplane or glider designed according to the invention.

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Fig.1a

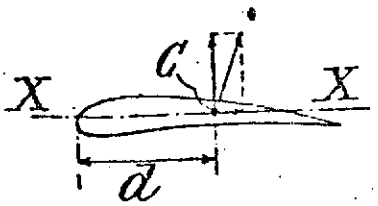


Fig.1b

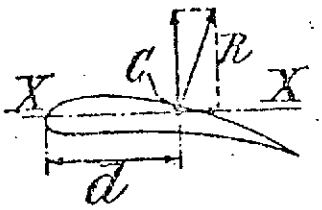


Fig.1c

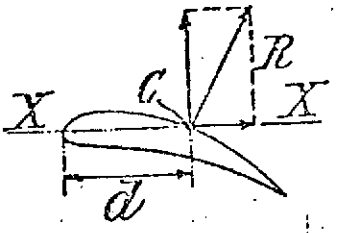


Fig.2a

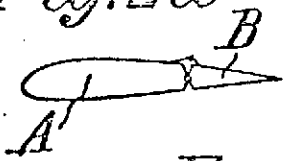


Fig.2b

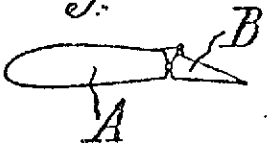


Fig.2c

Fig.3

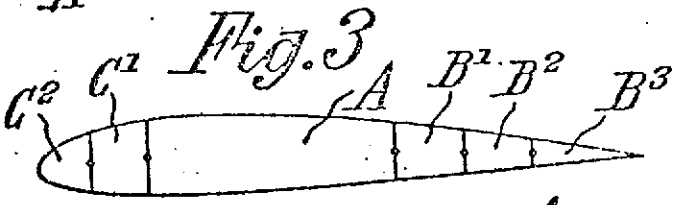


Fig.4

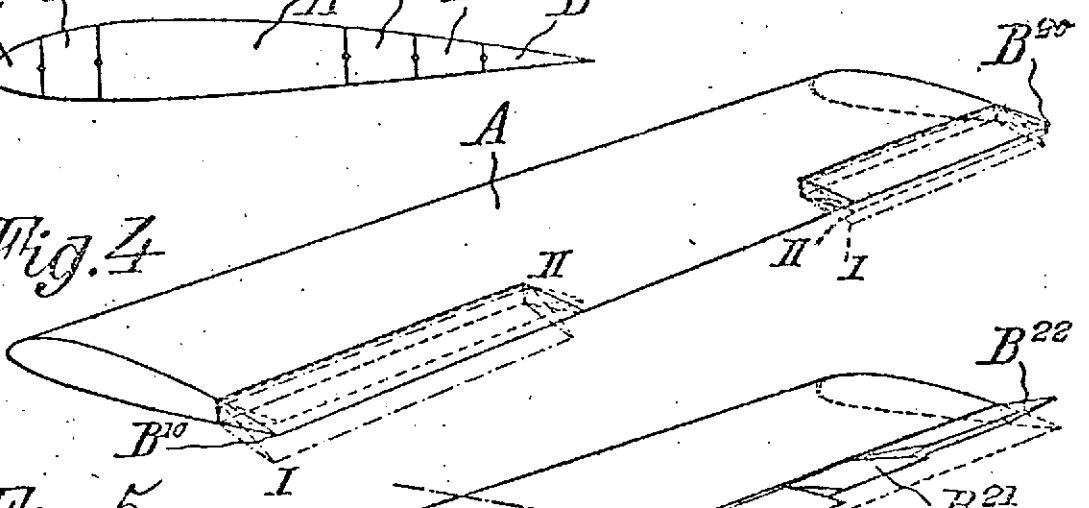
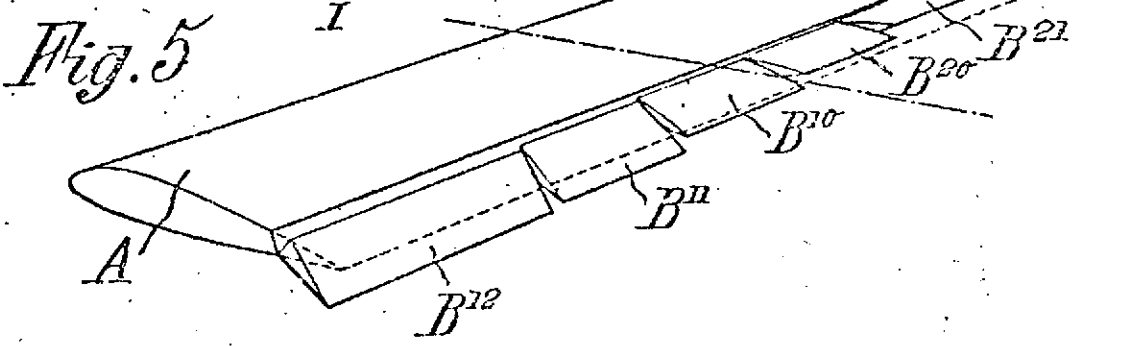


Fig.5



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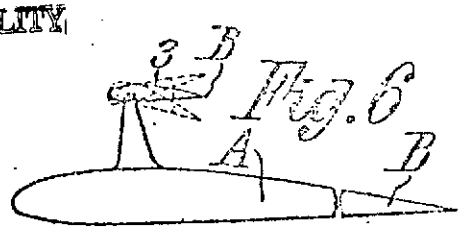

Fig. 6

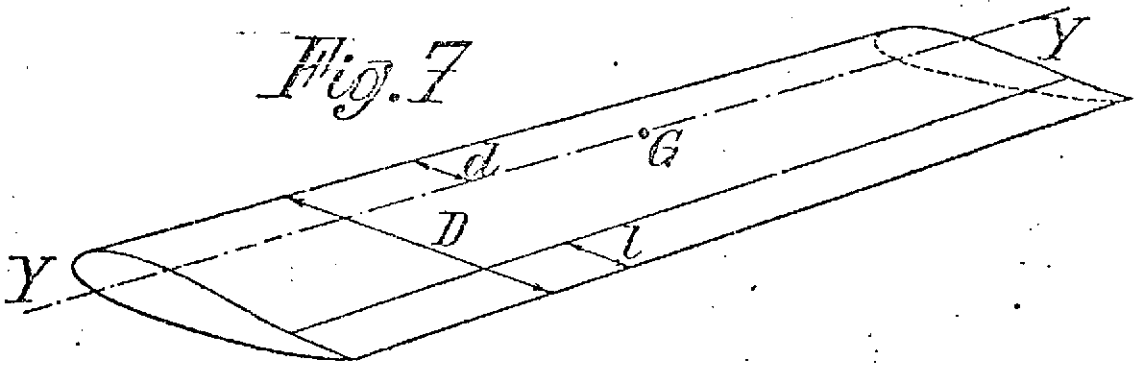

Fig. 7

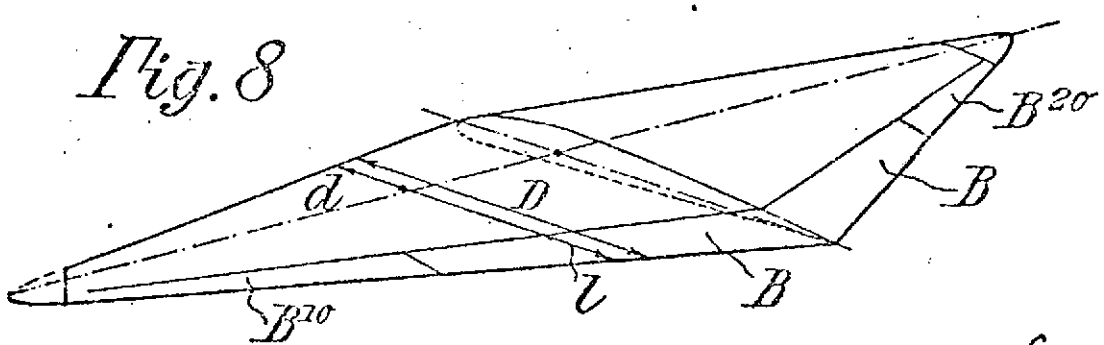

Fig. 8

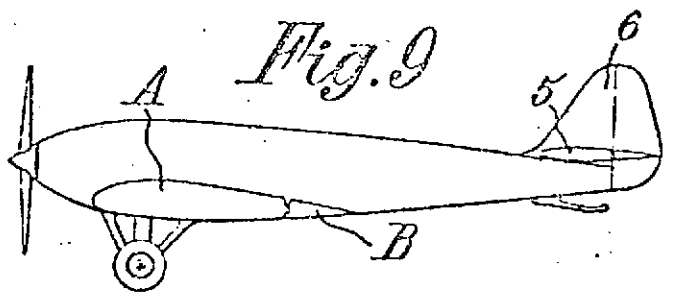

Fig. 9

Fig. 10

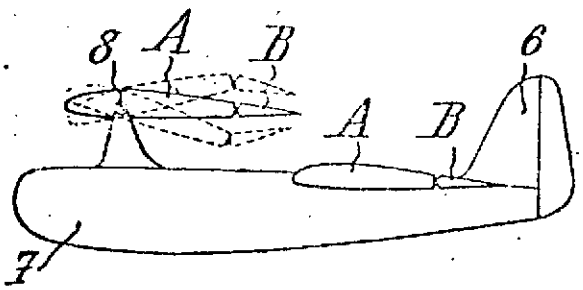

Fig. 11

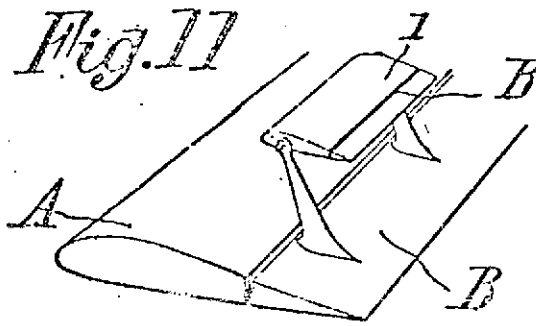

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Fig. 12

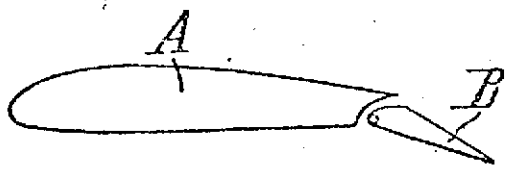

Fig. 13

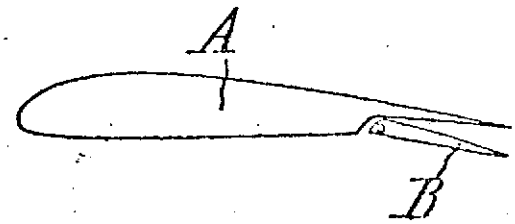

Fig. 14

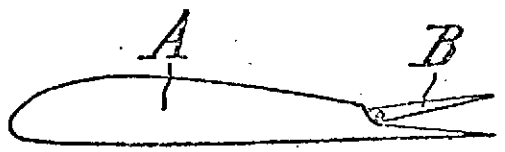

Fig. 15

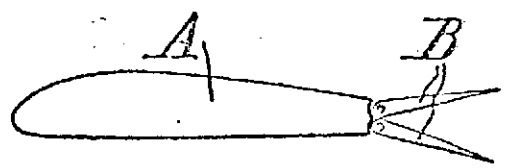

Fig. 16

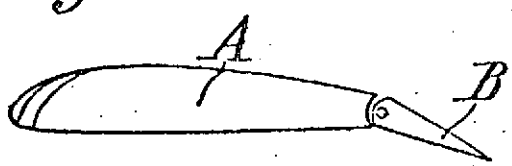

Fig. 17

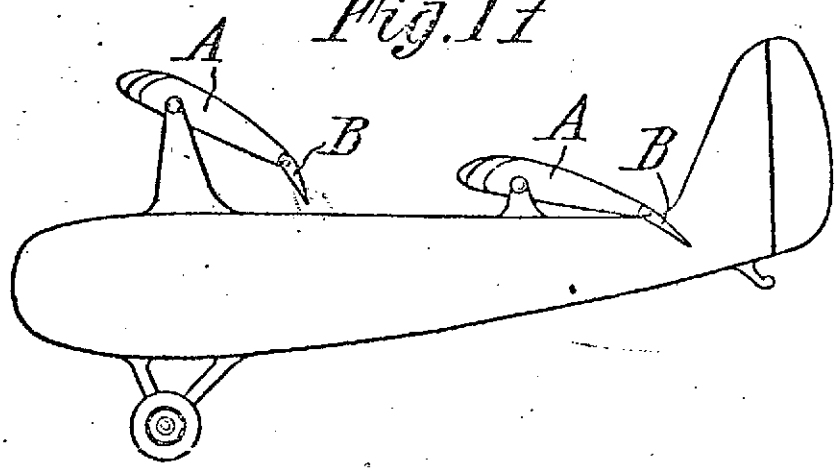

Figure 11 shows, in partial perspective, a wing according to a further form of development of the invention.

Figures 12 to 16 show, in cross section, various wings according to further forms of development of the invention.

Figure 17, finally, visualizes an airplane designed according to the invention with lifting surfaces lying behind one another in tandem, viewed from the side.

The principle which is basic to the invention is depicted in Figures 1a, 1b, 1c, in which the effects of a change in the angle of attack are explained. These figures show the same surface which, however, has a different angle of attack with respect to the path X-X each time. For each angle of attack the profile is changed in such a manner that the resultant R always passes through the same point C, which is a distance *d* behind the front edge of the surface in question.

In order to change the profile of the lifting surface, the surface is equipped with flaps along at least one edge. For example, surface A (Figures 2 and 3) can be connected with at least one flap B, which is located at the back edge of the surface A (see Figures 2a, 2b, 2c). This flap B may, for example, receive a greater angle of deflection with respect to the surface A, corresponding to how much the angle of incidence of the whole increases with respect to its path of motion.

At the front edge of part A of the surface one can also mount at least one variable flap. Finally, one or more flaps may also be arranged at the back edge as well as at the front edge of the surface of part A. Thus, for example, the object of Figure 3 shows three elements B^1, B^2, B^3 at the back edge of part A and two elements C^1, C^2 at the front part of this

piece.

The flaps B or similar items are for example hinged in such a manner that the hinge axis could possibly be displaced back. The flaps B can be compensated with the help of compensation flaps I (Figure 14).

According to the invention, the above flaps B are steered automatically in such a manner that the resulting pressure center always goes through the same point of the total surface, for variable angle of attack and for variable velocity of the lifting surface in the gas or liquid flow surrounding it. Depending on the individual case, the flap deflection can be in the same sense as the changes in the relative orientation of the whole (Figures 1a and 2) or in the opposite sense (Figure 10).

The items serving to change the flap position can also be steered as a function of the gangue of the motor(s) of the aircraft to which the surface of variable profile belongs; this is in order always to hold the pressure resultant at least approximately at the same place.

The elements for automatic steering of the surface profile, in order to hold constant the resulting pressure center at a definite place, can also be coupled with fore and aft control. The connection with fore and aft control is especially recommended when the deformation of the profiles should result as a function only of the angle of attack.

Let us point out here that the flaps B or a part of themselves form the pitch fin for steering the angle of attack. This is especially applicable for airplanes whose main plane structure is limited to the airplane wing (airplane with no

tail), or for airplanes with hinged surfaces - this case is described in more detail below.

The automatic steering device for changing the profile form can also be formed by an indicating device for the angle of attack or for the aerodynamic lift, by means of a pendulum, a gyroscope, a velocity or an acceleration indicator, a height measuring device, a statoscope, or similar items.

If the steering device for the change of the profile form is connected with the motors, then these may, for example, act via a tachometer which activates a relay. In place of the tachometer a ventilator or a pump may be used, whose variable pressure acts on a lever system. This lever system is, for example, that which connects the flaps B with the pitch fins or with some other system working as a function of the angle of attack. The lever system is used in such a manner that one obtains the best profile for each angle of attack, whereas the variable pressure of the ventilator of the pump, on the other hand, acts on the lever system in such a manner that the flaps B can fulfill their stabilization role for each trim. /3

If necessary, the flaps B can yet play a further role; individual ones can be used as wing flaps which serve to produce a sideways restoring or tilt moment. If, for example, it is a matter of an airplane wing (Figure 4), then one can arrange two flaps B^{10}, B^{20} at the back edge of this wing in the vicinity of its ends. The inner edge of these flaps, for example, starts in the middle of the wingspread or at a point which is even closer to the longitudinal axis of the airplane than the middle of the wingspread. The flaps B^{10}, B^{20} are connected with the steering of the direction of the airplane in such a manner that they can simultaneously be extended in the same sense (position I); thus they at least change the form of the

profile (depending on the angle of attack) in the end parts of the lifting surface, in which the changes of the resulting pressure center with respect to the torsion loads are the most dangerous. These torsion loads are brought about by changes in the wing skeleton. The flaps B^{10}, B^{20}, however, can also be extended in the opposite sense, and more precisely, with the same or with various angles of extension, in order to create a tilt or a restoring moment in this manner.

Of course, one can also equip the middle part of the lifting wing with flaps B, which then only have the job mentioned first. Such a construction is shown in Figure 8.

With respect to the direction of torsion, one can also make use of the following measures, which if necessary can be used alone. According to these measures, several flaps, B^{10}, B^{11}, B^{12} and B^{20}, B^{21}, B^{22} are placed on both sides of the longitudinal axis of the airplane, and more precisely along the whole wing spread available or along only a part of this wing spread. Both of these groups of flaps can be extended in the opposite sense, and more precisely in such a manner that the angle of deflection of the individual flaps of each group are different and increase towards the outer end of the lifting surface. By means of such an arrangement one can avoid too large flow differences at the edge of the flaps without simultaneously increasing the load resting on the oars too strongly. This load can also be decreased by means of compensation devices. In this manner the local torsion loads, which arise from the fact that the flaps extend in the opposite sense, can be diminished, whereas at the same time the air flow is improved.

The sideways tilt or restoring moment can also be maintained by some other method, for example, with the help of auxiliary wings 3, which are situated outside of the main plane

structure (Figure 6), so that they do not produce any moment of distortion. These auxiliary wings can, according to the invention, themselves be equipped with flaps B or similar devices.

The invention is applicable for all types of wings or main plane structures, and more precisely the wings may have the same depth along their whole wingspread (Figure 6), or they may possess variable depth (Figure 8). In addition, the profiles can be homothetic (similar in all cross sections and oriented the same way) or non-homothetic.

The invention is also applicable for airplanes with separate tail units (Figures 9 and 10) or for airplanes without separate tail units; for the latter the main plane structure is limited to a single wing, which as the case may be, can encompass all airplane parts ("wing-only-airplane", Figures 7 and 8).

In each individual case the characteristics of the flaps, that is to say their form and especially their relative depth and their relative angle of attack, must be separately calculated. This is so that one achieves the smallest possible motion of the pressure center (of the resultant of the forces acting on the wing), in spite of the changes of the angle of attack of the whole.

For example, let us assume that the invention is applied to an airplane structure that only consists of the wing A (Figure 7), whose profile has an essentially constant chord D, and for which the angle of attack is the same from the canter towards the outer edge. In this case the flaps B have the constant chord.

$$I = \frac{x}{100} \cdot D$$

If D is variable but the profiles are homothetic, then the flaps B, which preferentially simultaneously represent the pitch fins, are designed in such a manner that their depth I is equal to $\frac{x}{100} \cdot D$ in each cross section. The profiles of these flaps are themselves also homothetic. If these flaps simultaneously have the same deflection, then the resultant of the action of the air on the wing in each individual profile - calculated over the whole wing span - always goes through the same point of this profile in flight. That is to say, the resultant always goes through the same point of the wing chord, independent of the angle of attack in flight. For the attitude of the resultant is determined by the position of the center of gravity in such an apparatus. The law of curvature which depends on the angle of attack is thus automatically satisfied. /4

The consequence of this is that no change of the static torsion load occurs in the hinges, whereas on the other hand the changes in the dynamic torsional stress are significantly reduced. One can even make the static torsional stress equal to zero by designing the hinges in such a manner that they experience no torsional stress for the attitude chosen for the center of gravity.

One can set up the points of equal relative chord d, which has been chosen for centering, along the whole wing spread on the same transverse line Y - Y, which goes through the center of gravity of the machine. In this case, the dynamic torsional stresses and the local torsional stresses as well as the general and the local inertial stresses are decreased still further. If the centering, that is to say the chord d, is chosen appropriately, then the invention also allows the possibility that a good longitudinal stability is maintained, no matter what the position of the flaps is. The value D preferentially lies between 15% and 25% of the average total chord of the profiles.

The apparatus mentioned above with no tail, which has a very great chord in its center and becomes thin towards the edges (Figure 8), is especially practical with respect to its inertial, physical and handling properties. For this apparatus the flaps B which go from the center to half of the span serve primarily for maneuverability about the transverse axis, because they act on the largest part of the wing surface. The flaps B^{10}, B^{20}, on the other hand, which reach from the middle of the span to the outer end of the wing, serve primarily for maneuverability about the longitudinal axis, for which they are especially suited due to their distance from the axis of symmetry.

The latter flaps, which for example are steered in the manner explained with Figure 4, have a large range of extension for maneuverability about the longitudinal axis. Since the flaps B^{10}, B^{20} act beside the middle flaps, they simultaneously reduce the loads which would appear in their use for maneuverability about the longitudinal axis, if the connection with the middle flaps were absent. Let us also further point out that the hinges of the wing ends are especially strong due to the basic shape of the wing, which is tapered to a point. This is in order to offer resistance to the torsional stresses, which are actually already quite diminished, The outline form in question also has the further effect of also reducing the turning (yaw) effect that the flaps have on course stability.

If it is a matter of a wing with non-homothetic profiles, but with the same c_{m_0} and with the same angle for zero aerodynamic lift, then a result similar to that described above is achieved with flaps of the same relative chord and the same extension over the whole wing span.

For twisted wings the flaps may also be twisted. In order

also to satisfy the condition here that the resultants R are to remain at the same points of relative chord of the wing profiles, the flaps B, for example, receive corresponding changes in their relative chord or their attack or simultaneously in their relative chord and their attack. A realization of this idea may lead to a subdivision of these flaps. If from the start no motion of the pressure center occurs in individual parts of the wings, then one does not need to equip these parts with flaps B; rather, in these parts one only arranges for flaps to guarantee the sideways maneuverability.

The devices described above are also used if the invention is to be used for airplanes with a tail plane attached at an arbitrary place, be these airplanes one-, two-, or multi-planes (Figures 9 to 11). The same is true for applying the invention to airplanes with wings arranged behind one another in tandem (Figure 10), whether these are displaced with respect to each other or not, and whether these lie close together or far from each other. In the cases mentioned the motion of the flaps B of the wing(s) is connected with those of the rudders or other items which influence the fore and aft control of the machine, that is to say, its longitudinal inclination.

The invention is also applicable if the lifting wing A is hinged to the airplane fuselage (Figure 10). Even if it is a /5
matter of such hinged surfaces, these hinged surfaces can also be equipped with flaps B. These flaps are hinged in such a manner that the resultant always lies in the vicinity of the hinge axis S (Figure 10) or goes through this axis. The flaps in question can, even in these cases, be connected with a stationary part of the apparatus or can be steered directly in such a manner that they simultaneously play the role of the rudder steering the angle of attack. Here the law valid for the motion of extension must be observed precisely. If the lifting

surface is then hinged about its axes in the same manner as for no-tail devices, then the lifting surface turns about the center of gravity of the device.

For an airplane with hinged front and back lifting surfaces or with hinged lifting surface and hinged tail plane the same devices can be used for the front and back lifting surface or for the lifting surface and the tail plane, irrespective of what the position of these parts is.

Let us note that the invention in any case gives the possibility of giving the surfaces profiles which correspond to the special respective conditions of operation. Especially, surfaces developed according to the invention can receive a profile that carries with it a higher lifting capacity. Specifically, for small angles of attack, which correspond to large velocities, the profiles recieve a central line which is bent only slightly or not at all or which shows a double curvature with point of inflection. On the other hand, the central line is bent strongly for large angles of attack, corresponding to small velocities.

The invention can furthermore be applied to surfaces which are equipped with devices for increasing the aerodynamic lift or with devices for braking or with devices of both types. In this case, too, the resultant is held in the same point of the profile, in the range of customary angles of attack, in spite of changes in the angle of attack. The flaps B may be formed by the customary aerodynamic lift flaps or by the braking flaps (Figure 16) or by parts of these flaps. The slit can be adjustable. The flaps in question or their parts are of course steered in a manner in accord with one of the principles of the present invention.

One can also set the flaps on the under side (Figure 17) or on the top side (Figure 18) or simultaneously on the under and on the top side of the wings. In the latter case the hinging point can be the same for both flaps, or two different hinging points may be planned. The profiles of the wing, the flaps, and their extension must be chosen in such a manner that the given law is satisfied.

One can also combine a front slit, which is either constantly open or which can be closed with the help of automatic or non-automatic devices, with a flap B that works with or without a slit (Figure 20). This flap is steered in such a manner that the pressure center stays stationary in spite of the combined changes in the angle of attack and the slit opening.

The devices designed according to the invention for changing the wing curvature can also be applied simultaneously with suction or blowing devices for the boundary layer, or with systems that show a number of slits.

The devices mentioned above, which work with slits, can also be used with hinged tail planes and with airplanes with lifting surfaces lying behind one another in tandem, or with similar arrangements (Figure 21).

At the present curvature flaps are connected with the lifting surfaces of aircraft, whose change in length is in some cases connected with the displacement in the fore and aft control. These known devices, however, evidently have nothing in common with the invention, since they have never been developed such that with their help the total profile of the surfaces in question could be changed according to a law known in advance, which depends on the flight conditions of the machine and especially on its angle of attack. Just the

change according to such a law is, however, the main point of the invention.

If the flaps B are arranged in the manner characteristic of the invention, then they are steered, as is described above, in such a manner that their motions correspond in each case to the named law, and, more precisely, this is determined by aerodynamic or hydrodynamic experiments. The law itself is determined by an aerodynamic calculation, if the mathematical quantities are given in sufficient number, as is the case for mathematically determined profiles. Otherwise the law is determined by experiments in the laboratory or by experiments on models in natural size. As soon as this law has been determined and the mechanical devices (or other devices) for steering the wings B are connected with the latter in the sense of the law, then one can easily achieve that the resultant always goes precisely /6
or approximately through the same point each time the machine is steered when changing from one angle of attack to another angle of attack.

If the flaps are steered as a function of a variable operational parameter of the airplane, for example by means of an automatic steering apparatus or simply depending on the motors, then one can hold the machine in a certain trim position with the help of flaps automatically displaced in a stabilizing direction. This position can correspond to certain flight conditions, for example horizontal flight. The automatically steered flaps act especially on the tail or nose heaviness moments, which appear for changes in the motor rpm and more precisely for slow movements (idling) of the latter. Finally, let us again point out that the points made above about the execution and the application of the invention are only made as examples and that the invention is not limited to the forms of execution and application mentioned.

PATENT CLAIMS:

1. Lifting surface for airplanes whose profile is variable by means of movable flaps or similar items which are attached to at least one edge of the lifting surface, characterized by the fact that the change in the surface profile is automatically steerable as a function of the angle of attach in such a manner that the resulting pressure center always stays at least approximately at the same place.

2. Lifting surface according to claim No. 1, characterized by a steering device controlled by the surface velocity, by means of which the surface projile is automatically variable (for changing velocity) in such a manner that the pressure center always stays at least approximately at the same place.

3. Lifting surface according to claim No. 1, characterized by having the elements serving to change the surface profile to be steerable by an automatic steering deivce working as a function of an operational variable of the machine. Here these elements, for example, are connected to an indicating device for the angle of attack or for the aerodynamic lift, to a pendulum, a gyroscope, a velocity or an acceleration indicator, an altitude measuring device, a stratoscope and similar items, to the motor(s) or to a device for automatic airplane steering.

4. Lifting surface according to claim No. 3, characterized by having the elements working as a function of the motor velocity, for example, a tachometer or a ventilator driven by the motor acting on the hinged levers, by means of which the elements causing the change in profile (especially the flaps (B)) are connected to the fore and aft control.

5. Lifting surface according to claim No. 1, characterized by the chord for the flaps (B) being proportional in each profile to the appropriate profile chord (D) of the main part of the surface. This is in such a manner that the profile depth (I) corresponds to the expression $I = \frac{x}{100} \cdot D$.

6. Lifting surface according to claim No. 5, characterized by having the points of the profiles through which the pressure resultants of each profile pass, lie on a transverse straight line (Y - Y) which passes through the center of gravity of the machine.

7. Lifting surface according to claim No. 1, characterized by the fact that for non-homothetic wing profiles, the flaps preventing the migration of the pressure point shows variable chords or variable angles of attack or both.

8. Hinged lifting surface according to claim No. 1, characterized by having the flaps (B) extend in such a manner that the pressure resultant of the surface always passes through the hinge axis (8) of the hinged surface, or through a point lying close to this axis.

9. Lifting surface according to claim No. 1, characterized by having the flaps (B) hinged, on the one hand, in the same direction so as to make the pressure point immobile, and on the other hand, in the opposite sense as transverse rudders.

10. Lifting surface according to claim No. 9, characterized by having additional flaps (B) attached, between the flaps attached to the wing ends (B^{10}, B^{20}) that are hinged in both the opposite and in the same direction. These additional flaps are only hinged in the sense of determining the pressure points of the profiles.

11. Lifting surface according to claim No. 9, characterized by attaching groups of flaps (B^{10}, B^{11}, B^{12} and B^{20}, B^{21}, B^{22}) on both sides of the airplane longitudinal axis. These are hinged in groups in the opposite sense, whereas within each individual group the deflection angle of the individual flaps increases from the middle axis towards the end of the lifting surface. /7

12. Lifting surface according to claim No. 1, characterized by equipping it with a front slit of variable opening width in addition to the flaps (B). The flaps (B) are steered in such a manner that the pressure center stays immobile for changes in the slit width and the angle of attack.

13. Lifting surface according to claim No. 1, characterized by equipping it with a suction or blowing system for the boundary layer in addition to the flaps (B).

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